Proceedings of the 2009 IEEE International Conference on Systems, Man, and Cybernetics
San Antonio, TX, USA - October 2009

Information Systems and Social Legitimacy

Scientific Visualization of Water Quality

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***Abstract*—This paper addresses the challenge of social legitimacy issues for the technical solutions to environmental problems, and the role of Information Systems to resolve such issues. The paper outlines the Georgia Watershed Information System (GWIS), a comprehensive environmental information system, and one of its scientific visualization interfaces. This paper presents a novel scientific visualization tool based on unique components and features of GWIS. The visualization tool uses data and mapping services of GWIS to create dynamic visualizations and animation of water quality observations. A case study is demonstrated for visualizing water quality observations for dry and wet weather conditions on urban Weracoba Creek (Colombus) and its BMP (Best Management Practice), which might help to deal with issues of storm water (storm sewage) pollution control and management. The results show that the scientific visualization interface might support the prospective role of Information Systems in trying to resolve issues of "social legitimacy" surrounding the technical proposals with respect to re-engineering the city's infrastructure.**

***Keywords*—scientific visualization, information systems, social legitimacy, sustainability, water quality**

I. INTRODUCTION

There is a growing interest by researchers and general public to sustainability issues in the environment. It is an important challenge to achieve social legitimacy, one of the triple bottom lines for sustainability [1], in environmental studies along with the environmental benignity and economic feasibility. The pre-eminent role of social legitimacy is discussed extensively within the framework of triple-bottom-lines of accounting for sustainability in the water sector [2]. However, few studies have been carried out to explore how Environmental Information Systems (EIS) can help achieving social legitimacy of practical action for tomorrow in sustainability issues [3]. While 3 papers in this session [4, 5, 6] discusses issues on environmental benignity and economic feasibility aspects of sustainability, this study is making a start in compensating for the absence of social legitimacy discussions.

The role of Information Systems (IS) in global environmental issues can be classified into three actions as automate, informate and transform [7]. Cash et al. [8] describes the relationship between the three roles as, "When information technology substitutes for human effort, it automates a task or process. When information technology augments human effort, it informates a task or process. When information technology restructures, it transforms a set of tasks or processes".

The public awareness of certain environmental issues can be increased through an IS by providing high quality environmental information in a timely and cost effective manner. Spatial information systems have been widely used to monitor changes in physical environment. It is important to find the link between environmental issues and a specific polluting source (point or non-point). This can be achieved through an information system that provides necessary tools to create scientific visualization of environmental observations or simulations connected to rich geographical content. Thus, environmental information becomes easily reachable and understandable by the stakeholders, and transparency of environmental issues is improved. Stakeholders are often in dialog with architects who have models and visualizations of the urban landscape/buildings in transitions to the future [9]. Stakeholders are not so often confronted with the need to think about/visualize the less obvious environmental features of water quality. Results of environmental studies have to be "packaged" and "visualized" in ways understandable to stakeholders, in order for that technical (expert)-stakeholder dialog to be opened as soon as possible. This study makes a start on experimenting with (a) how to visualize water quality and (b) how to combine this visualization with the architect's visualizations.

The purpose of this study is to provide a tool to make environmental observations and quantitative computational analyses available with a dynamic scientific visualization interface to increase the understanding of the environmental research by stakeholders. This study tries to build a bridge between water quality observation and simulation works, and general public by providing dynamic scientific visualizations and animations. The visualization tool allows stakeholders to better understand management options, improves their opportunity to participate in informed management decisions, and informs stakeholders about the consequences of those decisions. A case study is demonstrated for visualizing water quality observations for dry and wet weather conditions on urban Weracoba Creek (Colombus) and its BMP, which might help to deal with issues of storm water (storm sewage) pollution control and management. An interface is developed as a part of a web-based information system for Georgia watersheds, called Georgia Watershed Information System (GWIS) [10].

In parallel to this study, Feng et al [5] explore the implementation of a source separation strategy in the sewage (foul sewage) system in the north part of Metro Atlanta (Upper Chattahoochee watershed). Feng's model of sewage system in North Atlanta includes combined sewer overflows (CSO), since storm sewage and foul sewage issues are related, especially where sewerage is combined. At some stage the Atlanta-Chattahoochee case study might be extended downstream to include Columbus. Furthermore, there will be many similarities between handling stormwater problems in Columbus and in nearby Atlanta. These two studies are building towards each other, given the advantages of a natural and geographical problem spread from previous research studies. Even though Feng et al [5] discuss various scenarios for source separation, the main challenges are not only technical and economical, but also social [11]. Since the transition will affect people's habits, WWTP structure and technology, sanitary industry, and market, it is important to make these scenarios understandable and available to general public for achieving social legitimacy. Visualization of the various scenarios will improve stakeholders understanding, and allow better informed decision-making by the non-expert user.

II. METHODOLOGY

The primary purpose of GWIS is initially to record and present the work of the Environmental Process Control Laboratory (EPCL) of the University of Georgia, which was essentially about the monitoring and modeling of the water environment required to move towards a "smart" urban water infrastructure (a 0% reconstruction strategy, [6]). The principal functionality of GWIS is to provide a platform for integrating state-wide efforts in environmental information collection, collation, storage, analysis, retrieval, and dissemination to all potential stakeholders. Several data management, modeling, visualization, mapping and resource management tools for watersheds, as well as interfaces for integration across diverse and dispersed data and mapping sources, are included in GWIS.

The client-side user interface of GWIS provides interaction with data, models and analytical tools, visualization and mapping. The management database (Fig. 1a) controls the interaction between each component and related interfaces, warehouses and web services. GWIS has been populated with high-volume high-quality (HVHQ; near continuous) water quality data acquired during field monitoring campaigns over the past 11 years with the EPCL, as its initial point of departure. GWIS provides a unique user experience with a simple and robust user interface, providing dynamic content with AJAX web technology, clear user instructions, info boxes for related information, auto complete and various controls for easy user input, which will also provide data consistency through the system.

GWIS has six main components with the following tools and features:

- *Data Component:* Data management, sharing and export, data web services, integration interfaces to distributed sources (e.g. USGS daily and real-time water quality datasets), and connections to site related sources.
- *Visualization:* Static and dynamic (Fig. 1b) line plots, statistical plots, multi-dimensional scatter and histogram charts (Fig. 1c), and dynamic scientific visualization interface.
- *Analysis:* Integrated analysis environment providing descriptive statistics, interpolation analysis, correlation and missing data analyses with Self Organizing Maps (Fig. 1d).
- *Modeling:* Integrated modeling environment providing advanced physical models (e.g. Watershed Water Quality Simulator).
- *Maps:* Online mapping capabilities with rich geographical content, various map types (Fig. 1e – e.g. city, terrain, satellite, 2D/3D maps, and etc...), Keyhole Markup Language (KML) and overlay support on maps (Fig. 1f), USGS Dynamic Information Interface [12], and support for various online map services. KML is a file format used to display geographic data on 2D maps and 3D Earth browsers.
- *Digital Library:* Site related digital resources, detailed site description from GWIS and USGS, site description web service, meta-data generator, and wiki retriever for watershed related terms.

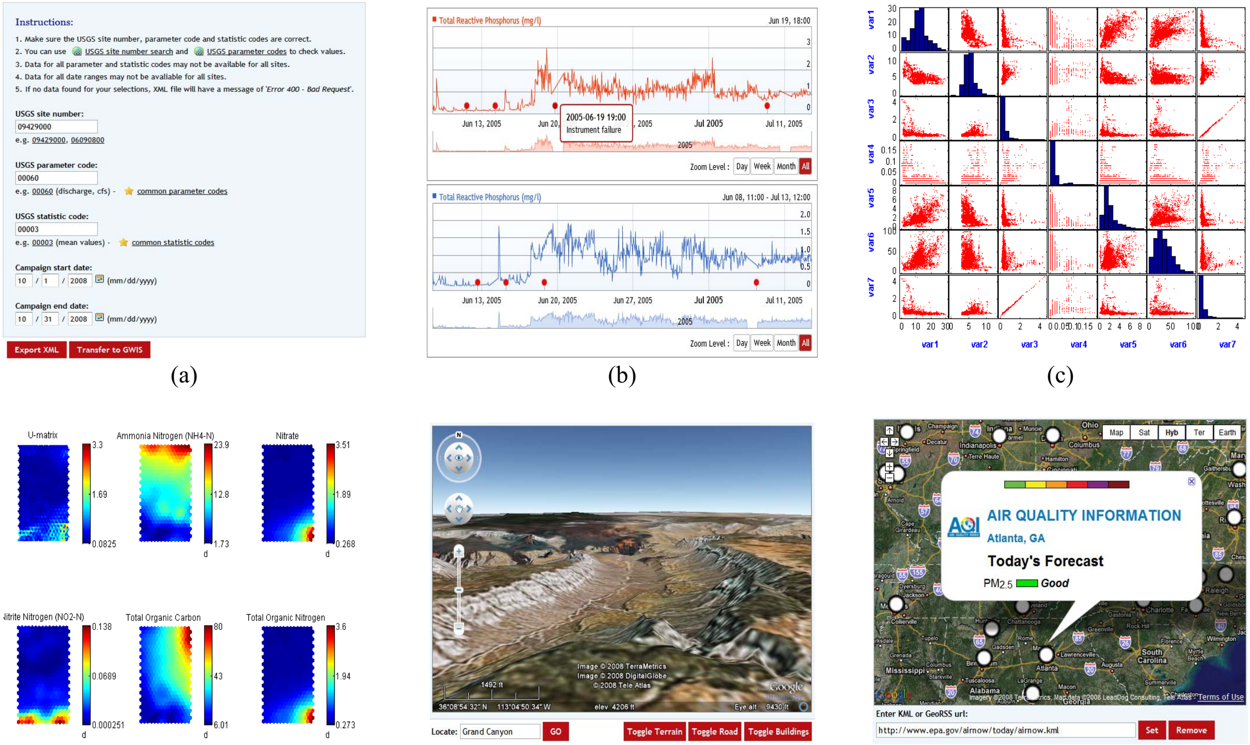
This study demonstrates an online tool to generate scientific visualizations and a dynamic animation interface for water quality observations and simulations. A case study is carried out by using the data of the urban Weracoba Creek watershed and its BMP project [13]. Weracoba Creek, an urban stream in Columbus, Georgia, is a tributary to Bull Creek and the Chattahoochee River. Location of the Weracoba Creek and the BMP site is given in Figure 2.

An interface is built as a part of visualization component of GWIS as shown in Figure 3. Several web technologies are used to build the interface such as PHP, mySQL, AJAX, Javascript, JSON, JQuery Javascript library, Google Map Services, and HTML. Having unique data and mapping tools in GWIS, makes it easier to build such a scientific visualization interface. GWIS does not only provide high-volume high-quality water quality data and models in the system, but also integrates distributed data and mapping sources.

The interface communicates with data and mapping services components of GWIS to visualize data on rich geographic content. Much time and effort would be required to build such a visualization tool without an information system like GWIS. A centralized approach by using a comprehensive information system to manage data, carry out complex hydrological simulations and visualize results on dynamic maps on a web-based interface, will increase the involvement of non-expert stakeholders and general public to environmental issues.

Steps to carry out a general case study by using the visualization interface are as follows:

- Selecting observation sites and variables by navigating on the dynamic satellite map (minimum 2 sites, e.g. upstream and downstream).
- Adding additional markers on the map to identify river channel pattern. *GWIS automatically creates additional segments for river channel and generates observation data by interpolation for internal sections for smooth visualization at this step.*
- The interface is ready for visualization. Animation controls or slider can be used to visualize data on maps.



Instructions:

1. Make sure the USGS site number, parameter code and statistic codes are correct.
2. You can use USGS site number search and USGS parameter codes to check values.
3. Data for all parameter and statistic codes may not be available for all sites.
4. Data for all date ranges may not be avaliable for all sites.
5. If no data found for your selections, XML file will have a message of *'Error 400 - Bad Request'*.

USGS site number: 09429000
e.g. 09429000, 06090800

USGS parameter code: 00060
e.g. 00060 (discharge, cfs) - common parameter codes

USGS statistic code: 00003
e.g. 00003 (mean values) - common statistic codes

Campaign start date: 10 / 1 / 2008 (mm/dd/yyyy)

Campaign end date: 10 / 31 / 2008 (mm/dd/yyyy)

(a)

(b)

(c)

(d)

(e)

(f)

Figure 1. Sample screenshots from GWIS interface: (a) USGS daily data connection; (b) Dynamic visualization; (c) Statistical visualization; (d) Self Organizing Maps analysis; (e) 3D terrain map by Google Earth API; and (f) KML support on Google Maps API.

Slider allows users to go back and forth in time through the time series data for the observed water quality values. An animation can be played and paused from any point in time. Visualization and animation provides information that the non-expert user can easily understand and allows them to compare results of different scenarios. Color scale from dark red (highest concentration) to dark green (lowest concentration) shows the color for corresponding variable values.

III. RESULTS AND DISCUSSIONS

Two snapshots of the animation are captured and presented (Figure 4 and 5) along with the photos of the physical environment in which the color of the river changed to the same color from the animation. Figure 4 presents a dry weather condition where BMP is active. EPCL, BMP and a known point source (P.S.) locations are marked with labels along the river. Sediment concentration drops significantly after the BMP then slightly increases after the point source location. Photos from the physical environment show the BMP location and color change where the sediment concentration drops significantly.

Figure 5 presents a wet weather condition where BMP is active. Storm water is about to pass over the weir. Sediment concentration drops significantly after the BMP then slightly increases after the point source location. Water color on photos during the wet weather event (Fig. 5) is darker (orange, high concentration) before BMP site, and lighter (green, low concentration) after the BMP site when compared to dry weather (Fig. 4) conditions.

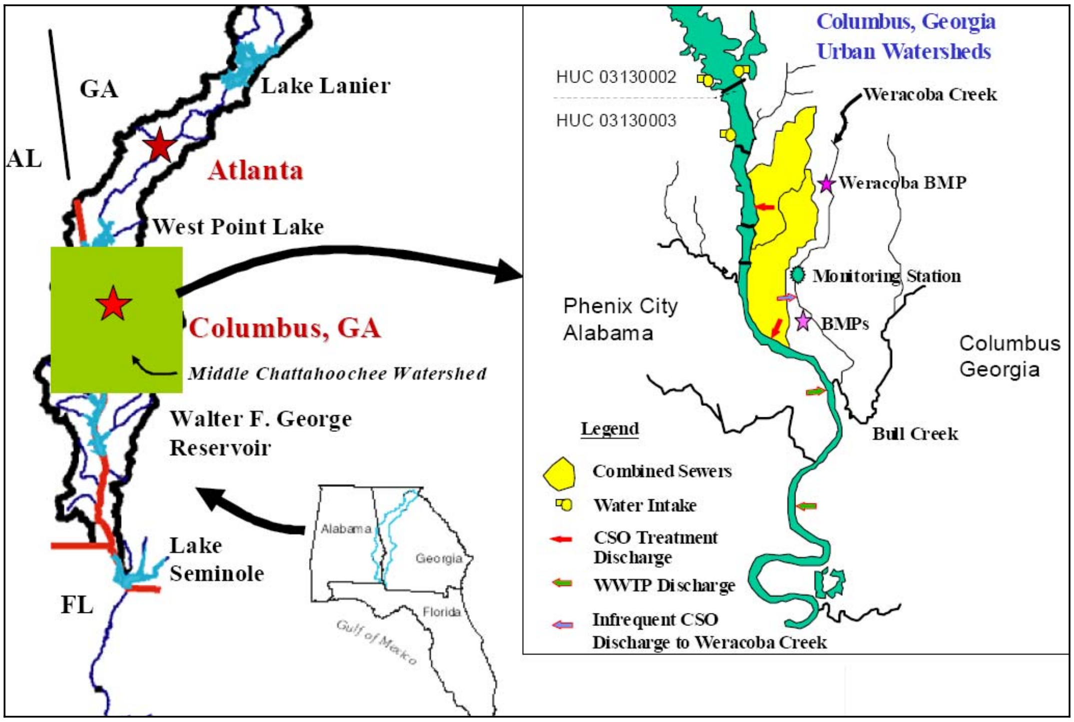
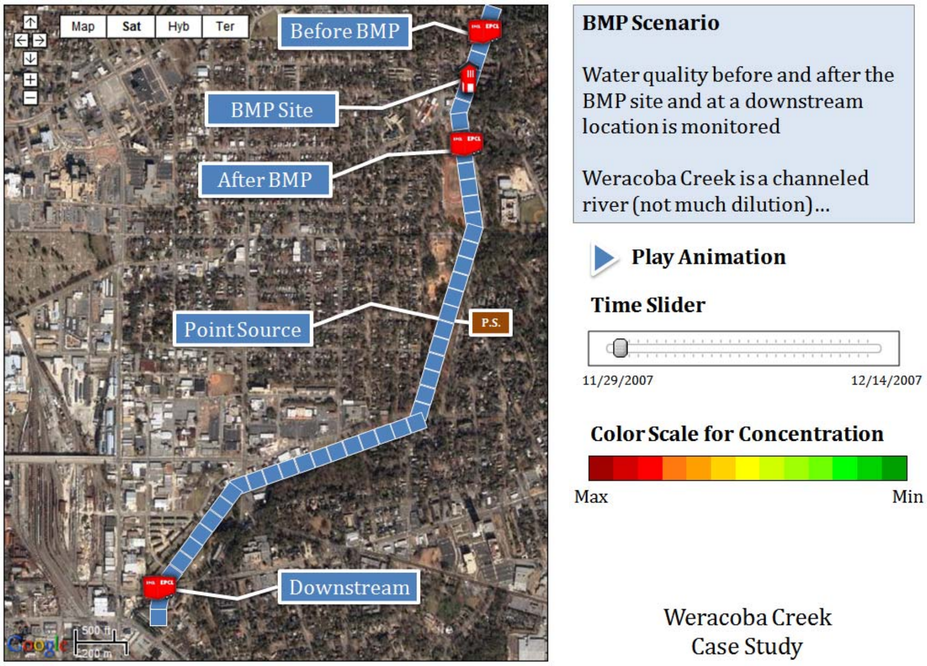


Figure 2. Location of the Weracoba Creek and the BMP site (image from Columbus Water Works, Final Weracoba Creek Report, 2008)



BMP Scenario

Water quality before and after the BMP site and at a downstream location is monitored

Weracoba Creek is a channeled river (not much dilution)...

Figure 3. The scientific visualization interface in GWIS

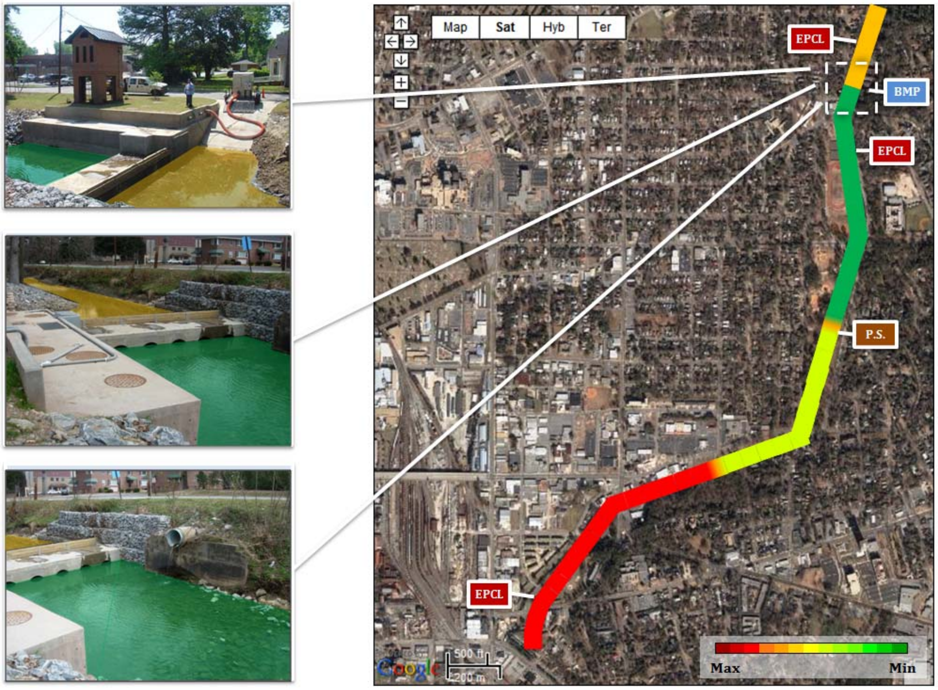


Figure 4. Dry weather condition where BMP is active

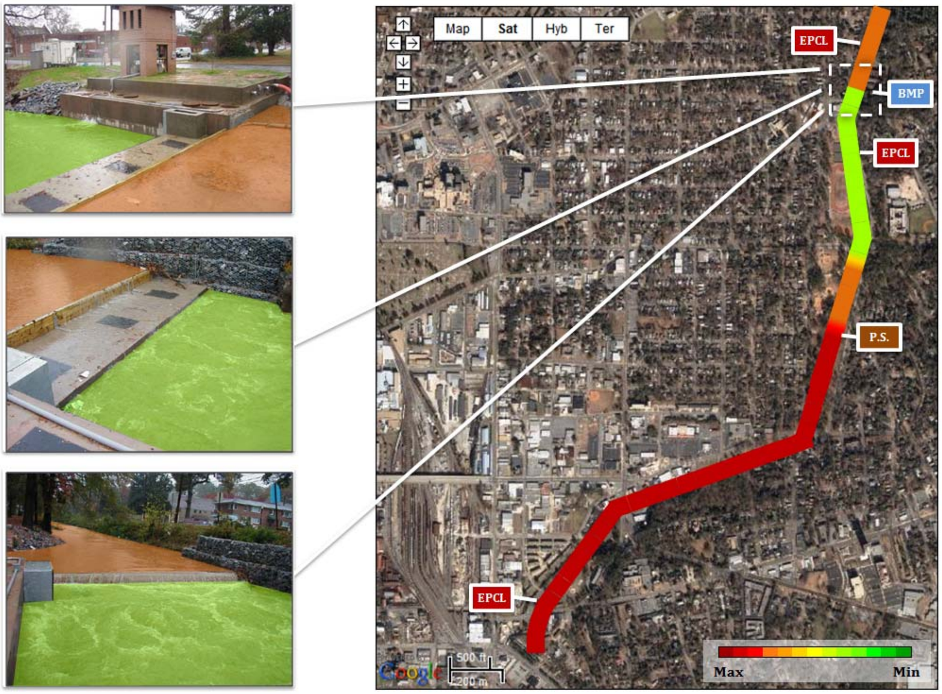


Figure 5. Wet weather condition where BMP is active

The figures visualize clearly the obvious effect of storm sewage and pollution reduction by BMP and concentration increase at the point source location. By providing necessary number of monitoring site data and locations, the interface helps general public to extract the possible point and non-point source locations and polluting entities. This might support the prospective role of Information Systems in trying to resolve issues of "social legitimacy" surrounding the technical proposals with respect to re-engineering the city's infrastructure.

IV. CONCLUSIONS

This paper tries to address the challenge of social legitimacy issues for the technical solutions to environmental problems and the role of Information Systems to resolve such issues. The paper outlines the Georgia Watershed Information System and one of its scientific visualization interfaces to create colorful spatial animation of water quality observations.

Even the advanced technical solutions to environmental issues will always be challenged with the need to engage the broader society and its institutions. A key issue is providing high quality environmental information in a timely and cost effective manner to general public and decision makers. Environmental Information Systems shows promises to contribute social component of the triple-bottom-lines of the sustainability with its unique scientific visualization capabilities.

While the environmental awareness increases with issues like water pollution, global warming and energy problems, we hope to provide tools by a comprehensive Information System to help understand the link between our physical environment and related research. Further research work is required to increase the role and benefit of the Information Systems on the issues of the social legitimacy for environmental concerns. However, we think that this case study shows the benefit that scientific visualization can provide as a tool for involving stakeholders in environmental decision making, engaging general public in understanding the natural and built environment, and thus furthering social legitimacy of the proposed technical solution.

While a novel scientific visualization of water quality can be useful in many ways, a more advanced interface can be built to include water quality modeling results in a future study (e.g. visualization of the model and data of Weracoba Creek, Colombus). The next steps, with respect to making much more use of both model and high-volume high-quality data in GWIS, would be using advanced data analysis features of GWIS to smooth and complete the data and present them as a colored animation on satellite maps. Same can be done for the model and the two could be compared side-by-side for detecting and interpreting mismatches.

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